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NATIONAL DAM INSPECTION PROGRAM. BIG BROWN DAM. SUSQUEHANNA RIV--ETC(U)
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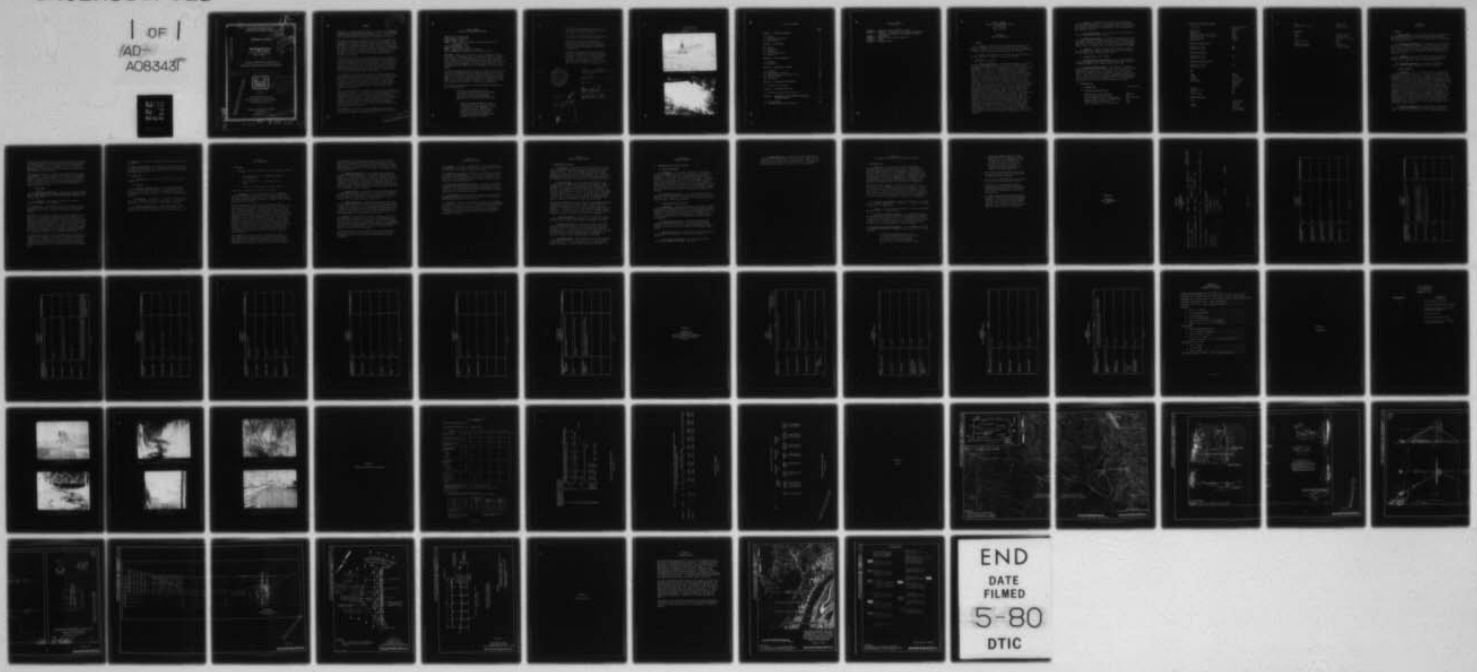

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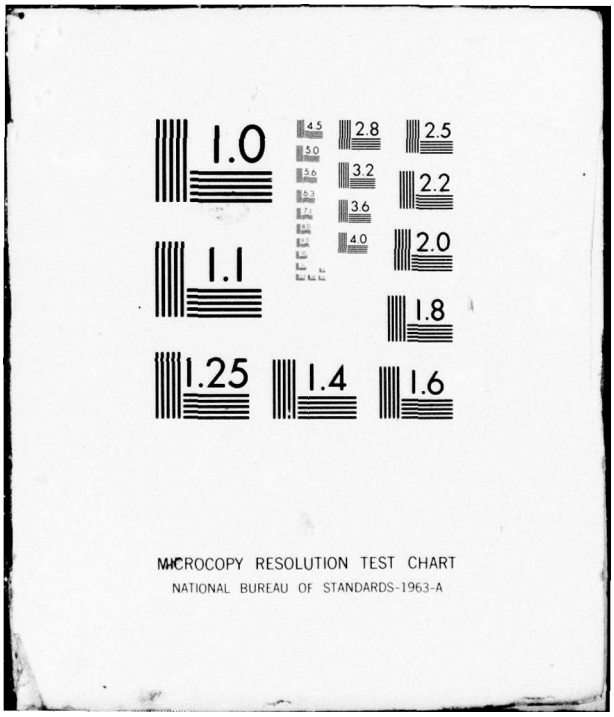
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SUSQUEHANNA RIVER BASIN,
BROWNS RUN, CAMBRIA COUNTY

PENNSYLVANIA

BIG BROWN DAM

(NDI I.D. NO: PA-00502,
DER I.D. NO: 11-1).

PHASE I INSPECTION REPORT
NATIONAL DAM INSPECTION PROGRAM

Lawrence D. Andersen

5 Mar 80

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PREPARED FOR

DEPARTMENT OF THE ARMY
BALTIMORE DISTRICT, CORPS OF ENGINEERS
BALTIMORE, MARYLAND 21203

BY

D'APPOLONIA CONSULTING ENGINEERS
10 DUFF ROAD
PITTSBURGH, PA. 15235

DACW31-80-C-0022

PREFACE

This report is prepared under guidance contained in the Recommended Guidelines for Safety Inspection of Dams, for Phase I Investigations. Copies of these guidelines may be obtained from the Department of the Army, Office of Chief of Engineers, Washington, D.C. 20314.

The purpose of a Phase I investigation is to identify expeditiously those dams which may pose hazards to human life or property. The assessment of the general condition of the dam is based upon visual observations and review of available data. Detailed investigations and analyses involving topographic mapping, subsurface investigations, material testing, and detailed computational evaluations are beyond the scope of a Phase I investigation; however, the inspection is intended to identify any need for such studies which should be performed by the owner.

In reviewing this report, it should be realized that the reported condition of the dam is based on observations of field conditions at the time of inspection along with data available to the inspection team. In cases where the reservoir was lowered or drained prior to inspection, such action, while improving the stability of the dam, removes the normal load on the structure and may obscure certain conditions which might otherwise be detectable if inspected under the normal operating environment of the structure.

It is important to note that the condition of the dam depends on numerous and constantly changing internal and external factors which are evolutionary in nature. It would be incorrect to assume that the present condition of the dam will continue to represent the condition of the dam at some point in the future. Only through frequent inspections can unsafe conditions be detected and only through continued care and maintenance can these conditions be prevented or corrected.

Phase I inspections are not intended to provide detailed hydrologic and hydraulic analyses. In accordance with the established Guidelines, the spillway design flood is based on the estimated "Probable Maximum Flood" for the region (greatest reasonably possible storm runoff), or fractions thereof. The spillway design flood provides a measure of relative spillway capacity and serves as an aid in determining the need for more detailed hydrologic and hydraulic studies, considering the size of the dam, its general condition and the downstream damage potential.

The assessment of the conditions and recommendations was made by the consulting engineer in accordance with generally and currently accepted engineering principles and practices.

PHASE I REPORT
NATIONAL DAM INSPECTION PROGRAM

[cont'd from p. i]

NAME OF DAM: Big Brown Dam
STATE LOCATED: Pennsylvania
COUNTY LOCATED: Cambria
STREAM: Brown's Run, a Tributary of the West Branch of the Susquehanna River
SIZE CLASSIFICATION: Small
HAZARD CLASSIFICATION: High
OWNER: Spangler Municipal Water Authority
DATE OF INSPECTION: November 27 and December 28, 1979

ASSESSMENT: Based on the evaluation of the existing conditions, the condition of Big Brown Dam is considered to be poor. Extensive swampy areas were observed along the toe of the dam. This condition, together with the steep downstream slope of the embankment (1-1/2 horizontal to 1 vertical), raises concern as to the continued stability of the embankment. In view of these conditions, it is recommended that the stability of the embankment be further investigated.

The flood discharge capacity of the dam was found to be at the lower limit of the recommended spillway capacity range of 50 percent to full PMF relative to the size and hazard classification of the dam. However, in view of the height of the dam (37 feet) approaching the upper limit of the size classification (40-foot height), the upper limit of the capacity range is considered to be applicable to this dam; therefore, the spillway is classified to be inadequate.

The following recommendations should be implemented immediately or on a continuing basis.

1. The owner should immediately retain a professional engineer experienced in design and construction of dams for detailed evaluation of the dam and appurtenant structures and to prepare and execute plans for:

   a. Controlling swampy conditions at the downstream toe of the dam and evaluating the stability of the embankment in view of these conditions. The detailed evaluation of the dam should include, but not be limited to, subsurface investigations, material testing, and seepage and stability analyses.

2. The structural and operational condition of the outlet facilities should be evaluated and necessary maintenance performed.

3. The crest of the embankment should be surveyed and low spots filled to design elevation.

4. Around-the-clock surveillance should be provided during unusually heavy runoff and a formal warning system should be developed to alert the downstream residents in the event of emergencies.

5. The dam and appurtenant structures should be inspected regularly and necessary maintenance performed. A review of the regional geology indicates that some deep coal mine workings may exist in the vicinity of the dam site. Therefore, future inspections should include a search for any indications of subsidence.

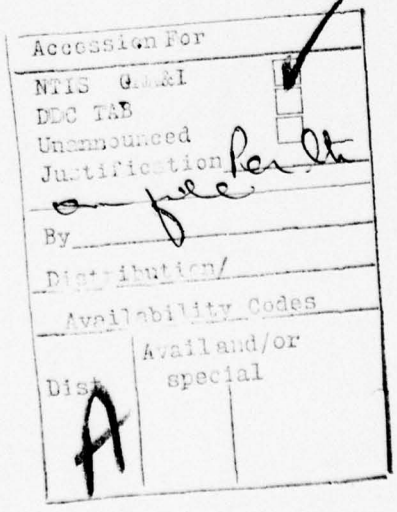
Lawrence D. Andersen, P.E.
Vice President

March 5, 1980
Date

Approved by:

JAMES W. PECK
Colonel, Corps of Engineers
District Engineer

31 March 1980
Date



Upstream Face

Downstream Face

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PHASE I REPORT
NATIONAL DAM INSPECTION PROGRAM
BIG BROWN DAM
NDI I.D. PA-502
DER I.D. 11-1

SECTION 1
PROJECT INFORMATION

1.1 General

a. Authority. The inspection was performed pursuant to the authority granted by The National Dam Inspection Act, Public Law 92-367, to the Secretary of the Army, through the Corps of Engineers, to conduct inspections of dams throughout the United States.

b. Purpose. The purpose of this inspection is to determine if the dam constitutes a hazard to human life or property.

1.2 Description of Project

a. Dam and Appurtenances. Big Brown Dam consists of an earth embankment approximately 290 feet long with a maximum height of approximately 37 feet from the downstream toe, and a crest width in the range of 8 to 11 feet. The downstream slope of the dam is 1-1/2 horizontal to 1 vertical and is protected with well-established grass. The upstream slope is protected by riprap extending to the crest level of the dam. The flood discharge facilities for the dam consist of a primary spillway incorporated into the outlet facilities and an open channel emergency spillway located on the right abutment. The outlet facilities consist of a 20-inch cast-iron supply line and a 20-inch cast-iron blow-off pipe. Flow through these pipes is controlled by valves located in a control tower which is situated on the downstream side of the crest through the embankment. When the blow-off valve is open, the flow would initially discharge into the control tower, which in turn is drained by a 20-inch cast-iron pipe extending from the control tower to the discharge channel at the downstream toe of the dam. A 24-inch riser pipe in the control tower extending from the supply line to the normal pool level constitutes the primary spillway. When the reservoir level is above the normal pool elevation, water in the riser pipe rises above the top of the pipe and spills into the control tower, which is then drained through the control tower drainpipe. The emergency spillway is a rock-cut channel on the right abutment, essentially rectangular in cross section with a base width of 22 feet. The crest of the emergency spillway is located about six inches above the normal pool level. The 20-inch blow-off pipe constitutes the emergency drawdown facility for the reservoir.

[cont'd on p. 11]

b. Location. Big Brown Dam is located near the headwaters of Brown's Run, approximately 2-1/2 miles upstream from its confluence with the West Branch of the Susquehanna River near Spangler in Barr Township, Cambria County, Pennsylvania. Plate 1 illustrates the location of the dam.

c. Size Classification. Small (based on 37-foot height and 76 acre-feet maximum storage capacity).

d. Hazard Classification. The dam is classified to be in the high hazard category. Approximately one mile downstream from the dam, Brown's Run flows through a residential area. It is estimated that failure of the dam would cause large loss of life and property damage in this residential area and further downstream at Spangler.

e. Ownership. Spangler Municipal Water Authority (address: Mr. John Weymer, Jr., Manager, Spangler Municipal Water Authority, P.O. Box 488, Spangler, Pennsylvania, 15775).

f. Purpose of Dam. Water Supply.

g. Design and Construction History. The dam was designed by a consulting engineer from Spangler, Pennsylvania, and constructed by Northern Cambria Water Company during 1909 and 1910.

h. Normal Operating Procedure. The reservoir is normally maintained at Elevation 1675, which is the top level of the primary spillway riser pipe located in the control tower. The crest level of the emergency overflow spillway is located at Elevation 1675.5. When the lake level is below the emergency spillway crest level, inflow occurring is discharged through the primary spillway. When the lake level is above Elevation 1675.5, inflow occurring is discharged both through the primary and emergency spillways.

1.3 Pertinent Data

a. Drainage Area — 0.55 square mile

b. Discharge at Dam Site (cfs)

Maximum known flood at dam site	Unknown
Blow-off pipe at maximum pool	60+
Gated spillway capacity at maximum pool	Not applicable
Ungated spillway capacity at maximum pool	613
Primary spillway (riser pipe)	30+
Total spillway capacity at maximum pool	643

c. Elevation, USGS Datum (feet)

Top of Dam	1680.3 (measured low spot)
Maximum pool	1680.3
Normal pool	1675
Upstream invert outlet works	1650±
Downstream invert outlet works	1641±
Maximum tailwater	Unknown
Downstream toe	1643±

d. Reservoir Length (feet)

Normal pool level	800
Maximum pool level	900±

e. Storage (acre-feet)

Normal pool level	51
Maximum pool level	76

f. Reservoir Surface (acres)

Normal pool level	4.6
Maximum pool level	5.5

g. Dam

Type	Earth
Length	290 feet
Height	37 feet
Top width	8 to 11 feet
Side slopes	Downstream: 1.5H:1V Upstream: 2H:1V
Zoning	No
Impervious core	Yes
Cutoff	Yes
Grout Curtain	No

h. Regulating Outlet

Type	20-inch cast-iron pipe
Length	175± feet
Closure	A valve downstream of the core wall

Access	Control tower
Regulating facilities	Valves at control tower

i. Spillway

Type	Rock-cut channel
Length	22 feet (perpendicular to flow)
Crest elevation	1675.5
Gates	None
Upstream channel	lake
Downstream channel	Rectangular rock-cut channel

SECTION 2
DESIGN DATA

2.1 Design

a. Data Available. The available information was provided by the Commonwealth of Pennsylvania, Department of Environmental Resources (PennDER), which contains design drawings, correspondence, and inspection reports.

(1) Hydrology and Hydraulics. As designed, the only overflow facility for the dam was the standpipe in the control tower which functioned as a primary spillway. No design information is available on this facility. The emergency spillway was constructed in 1922. Available information includes the design capacity of the emergency spillway.

(2) Embankment. Available information consists of design drawings, state inspection reports, and construction progress reports for post-construction work conducted during 1922.

(3) Appurtenant Structures. The available information consists of design drawings and state inspection reports.

b. Design Features

(1) Embankment. Plate 2 illustrates the plan, longitudinal, and transverse section of the dam. A typical cross section of the dam through the outlet facilities is illustrated in Plate 3. The embankment is shown to consist of a homogeneous fill with a concrete core wall located along the downstream edge of the embankment crest. A 1914 state inspection report indicates that a cutoff wall starting from a level about 2 feet above the normal pool elevation was extended 9 feet on the average below the natural ground surface. It is reported that the cutoff wall was 36 inches thick at the base level, and the thickness was reduced in 4-inch steps to a 12-inch thickness at the top of the wall. In the 1914 state report, the embankment materials were described as "select" and "ordinary" materials. The upstream half of the embankment consisted of select material, while the downstream half consisted of both select and ordinary material. In the downstream half, select material was placed against a concrete core wall. It is reported that all the embankment material was placed in 6-inch layers, sprinkled, and compacted by horse rollers.

(2) Appurtenant Structures. The appurtenant structures of the dam consist of a primary and emergency spillway and outlet works. As described in Section 1.2, a riser pipe situated in the

control tower incorporated into the 20-inch supply line constitutes the primary spillway. The details of the outlet works facilities are illustrated in Plate 3. The pipes through the embankment are shown to be founded on concrete cradles. Each of the pipes was equipped with a cutoff collar located approximately midway between the intake and the control tower.

The emergency spillway is a rock-cut open channel located on the right abutment. A typical proposed cross section of the emergency spillway is illustrated in Plate 2. In this detail, the spillway channel is shown to be 25 feet wide with its crest at Elevation 1677.5. However, approximate field measurements taken during this inspection indicate the crest level to be at Elevation 1675.5 and a flow width of 22 feet.

c. Design Data.

(1) Hydrology and Hydraulics. A state report entitled, Report Upon the Application of the Northern Cambria Water Company, dated June 8, 1921, indicates that the emergency spillway was sized for a capacity of 425 cfs.

(2) Embankment. The available information includes no quantitative data for the embankment.

2.2 Construction. Very limited information is available on the construction of the dam. As mentioned previously, the embankment material was placed in 6-inch layers and compacted with horse rollers.

Available records indicate that shortly after the completion of the dam, in 1914, a significant leakage was observed along the left abutment toe approximately 30 feet below the top of the dam. In 1921, an investigation was undertaken into the cause of this leakage by Gannett, Seely, and Fleming, Inc., of Harrisburg, Pennsylvania. The remedial measures consisted of construction of a partial clay cutoff wall on the upstream toe of the dam in line with the seepage location and grouting on the left abutment. Figure 4 illustrates the location of the grout holes. The emergency spillway was excavated during this period of remedial work at the dam site.

It appears that the remedial work undertaken was not successful in controlling the seepage. Various state inspections conducted after completion of the remedial work refer to the presence of a large leakage on the left abutment. Although references were found to indicate flow weirs were installed to monitor seepage quantities, available information does not include any records of these measurements.

2.3 Operation. No formal operating records are maintained for the reservoir.

2.4 Other Investigations. The only reported investigation was the investigation into the causes of leakage through the left abutment. This investigation was undertaken during 1921, details of which are described in Section 2.2.

2.5 Evaluation

a. Availability. The available information was provided by PennDER.

b. Adequacy

(1) Hydrology and Hydraulics. The available information consists of design discharge capacity of the emergency spillway. This information is not considered to be adequate to assess the conformance of the spillway capacity to the current spillway design criteria.

(2) Embankment. The available information includes no quantitative data on material properties, slope stability, or seepage analyses to aid in the assessment of the adequacy of design.

(3) Appurtenant Structures. Review of the design drawings indicates that no significant design deficiencies exist that would affect the overall performance of the appurtenant structures.

SECTION 3
VISUAL INSPECTION

3.1 Findings

a. General. The on-site inspection of Big Brown Dam consisted of:

1. Visual inspection of the embankment, abutments, and embankment toe.

2. Visual examination of the appurtenant structures.

3. Evaluation of downstream area hazard potential.

The specific observations are illustrated in Plate 5.

b. Embankment. The general inspection of the embankment consisted of searching for indications of structural distress, such as cracks, subsidence, bulging, wet areas, seeps and boils, and observing general maintenance conditions, vegetative cover, erosion, and other surficial features.

The most significant condition noted at the dam site was the presence of extensive swampy areas immediately below the toe of the dam. Ground in this area was found to be very soft. It appears that this swampy condition is caused by flow discharging into this area from the right abutment and underseepage. The flow from the right abutment seepage point was estimated to be on the order of 20 gallons per minute. This seepage point is located at the abutment/embankment interface about midheight of the dam. Flow from the swampy areas along the toe of the dam discharges into the primary spillway discharge channel through a small stream. Flow in this stream was estimated to be on the order of 30 gallons per minute. The flow at the major leakage point on the left abutment, which was reported to have existed since the completion of the dam, was estimated to be on the order of one-half to one cfs. Flow from the seepage points was found to be clear, showing no signs of internal erosion.

The alignment of the downstream face of the dam was found to be good, showing no visually perceivable indications of distress. Approximate slope measurements were taken at several locations on the downstream face except for the top four to six feet of the embankment where the slope was found to be about one horizontal to

one vertical; on the remaining portions the slope was reasonably within the design slope of one and one-half horizontal to one vertical. The crest of the dam was surveyed relative to the emergency spillway crest elevation and was found to be generally below the design crest elevation. The crest profile of the dam is illustrated in Plate 6.

c. Appurtenant Structures. The emergency spillway and the equipment at the operating level of the control tower, which consisted of two valve operators, were inspected. The water authority personnel indicated that although a ladder extends into the control tower from the operating level, due to the age of the dam, the strength of the ladder was questionable. Therefore, the inside of the control tower below the operating level was not inspected. The rock-cut emergency spillway channel was found to be free of obstructions to flow and in good condition.

d. Reservoir Area. A map review indicates that the watershed is predominantly covered by woodlands. A review of the regional geology (Appendix F) indicates that the shorelines of the reservoir are not likely to be susceptible to massive landslides, which would affect the storage volume of the reservoir.

e. Downstream Channel. Downstream from the dam, Brown's Run flows through a narrow, uninhabited valley for about one mile where it enters a residential area. Further downstream, Brown's Run flows through other residential areas near Spangler, Pennsylvania, where it joins the West Branch of the Susquehanna River approximately 2-1/2 miles downstream from the dam. A further description of the downstream conditions is included in Section 1.2d.

3.2 Evaluation. The presence of extensive swampy areas along the toe of the dam is considered to be a point of concern relative to the continued stability of the embankment. In view of this swampy condition, which is likely to affect the stability of the embankment, and the relatively steep downstream slope, further investigation of the stability of the embankment to formulate necessary remedial measures is considered to be advisable.

To the extent that can be determined from the visible portions of the outlet facilities, these structures were found to be poorly maintained. Inspection and evaluation of these facilities are recommended.

SECTION 4
OPERATIONAL FEATURES

4.1 Procedure. There are no formal procedures for the operation and maintenance of the dam. The reservoir is normally maintained at the top level of the primary spillway riser pipe.

4.2 Maintenance of the Dam. Maintenance of the dam is considered to be fair. The downstream face of the dam is covered with well-established grass, which appears to be periodically mowed. It was noted that no attempt has been made to observe or monitor seepage conditions along the downstream toe.

4.3 Maintenance of Operating Facilities. The operating equipment, consisting of two manual valve operators, was found to be in poor condition. The water authority personnel reported that the operational condition of the blow-off valve was questionable. Therefore, operation of the valve was not observed.

4.4 Warning System. No formal warning system exists for the dam. Telephone communication facilities are available via residences approximately one-half mile from the dam.

4.5 Evaluation. While the maintenance condition of the embankment is considered to be fair, the maintenance condition of the operating facilities is considered to be poor. The operational condition of the reservoir blow-off pipe was not observed. It is therefore recommended that the owner operate the blow-off valve and inspect the facilities inside the control tower and perform necessary maintenance as required.

SECTION 5
HYDRAULICS AND HYDROLOGY

5.1 Evaluation of Features

a. Design Data. Big Brown Dam has a watershed of 0.5 square mile and impounds a reservoir with a surface area of 4.6 acres at normal pool level. The flood discharge facilities for the dam consist of a riser pipe overflow primary spillway and a rock-cut emergency spillway located on the right abutment. The capacity of the emergency spillway, based on the available freeboard relative to the low spot on the crest of the dam, was estimated to be 613 cfs.

b. Experience Data. As previously stated, Big Brown Dam is classified as a small dam in the high hazard category. Under the recommended criteria for evaluating emergency spillway discharge capacity, such impoundments are required to pass the one-half to full PMF. The height of the dam (37 feet) which dictated the size classification of this dam is closer to the upper limit of the small size dam classification of 40 feet. According to the recommended criteria, dams at or above 40 feet in height are required to pass full PMF. Therefore, the upper limit of the recommended spillway capacity range is considered to be applicable to this dam.

The PMF inflow hydrograph for the reservoir was determined utilizing the Dam Safety Version of the HEC-1 computer program developed by the Hydrologic Engineering Center of the U.S. Army, Corps of Engineers. The data used for the computer analysis are presented in Appendix D. The peaks of the 50 percent and full PMF hydrographs were found to be 630 and 1260 cfs, respectively. Computer input and a summary of computer output are also included in Appendix D.

c. Visual Observations. On the date of inspection, no conditions were observed that would indicate the emergency spillway of the dam would not operate satisfactorily in the event of a flood.

d. Overtopping Potential. Various percentages of the PMF inflow hydrograph were routed through the reservoir, based on the discharge capacity of the emergency spillway starting from the normal pool level. It was found that the dam can pass 50 percent of the PMF without overtopping the low spot on the embankment. At full PMF, the low spot on the embankment would be overtopped for a duration of 4.8 hours with a maximum depth of 0.97 foot.

e. Spillway Adequacy. The spillway capacity is less than the recommended capacity of full PMF; therefore it is rated as inadequate. However, it is not considered to be seriously inadequate, because the capacity is larger than 50 percent of the PMF.

SECTION 6
STRUCTURAL STABILITY

6.1 Evaluation of Structural Stability

a. Visual Observations

(1) Embankment. As discussed in Section 3, the presence of extensive swampy areas along the downstream toe of the dam, in conjunction with the relatively steep downstream slope (1-1/2 horizontal to 1 vertical), is considered to be a point of concern relative to the continued stability of the embankment. The ground in the swampy areas was found to be very soft. This condition suggests the possibility of the presence of excess pore pressure in this area which may affect the stability of the embankment. In view of these conditions, the evaluation of the stability of the embankment to formulate necessary remedial measures is considered to be advisable.

(2) Appurtenant Structures. As discussed in Section 3, the appurtenant structures located in the control tower were not accessible for visual inspection. Therefore, the structural condition of these facilities could not be assessed.

b. Design and Construction Data

(1) Embankment. The dam was designed in 1909, when a limited understanding of geotechnical behavior of earth structures existed. Consequently, available design and construction information does not provide any quantitative data to aid in the assessment of the stability. Based on the visual observations, the static stability of the dam is considered to be questionable, requiring further investigation.

(2) Appurtenant Structures. Other than design drawings, no other design data are available to determine the structural adequacy of these facilities. The structural adequacy of these facilities should be reevaluated based on further detailed inspections.

c. Operating Records. The structural stability of the dam is not considered to be affected by the operational features of the dam.

d. Post-Construction Changes. The description of post-construction changes is included in Section 2.2.

e. Seismic Stability. In view of the concerns that exist relative to the static stability of the dam, the seismic stability of the dam is also considered to be questionable. Therefore, the seismic stability of the dam should be reassessed in conjunction with further investigation and evaluation of the embankment.

SECTION 7
ASSESSMENT AND RECOMMENDATIONS/REMEDIAL MEASURES

7.1 Dam Assessment

a. Assessment. The visual observations indicate that Big Brown Dam is in poor condition. In view of the presence of extensive swampy areas along the downstream toe of the dam and the steep downstream slope of the embankment, concern exists as to the continued stability of the dam. Based on these observations, detailed investigation of the embankment as an impounding structure is recommended. It is also recommended that in conjunction with a detailed investigation of the dam, the structural adequacy and operational condition of the outlet facilities be reevaluated.

The flood discharge capacity of the dam was found to be at the lower limit of the recommended spillway capacity range of 50 percent to full PMF relative to the size and hazard classification of the dam. However, in view of the height of the dam (37 feet) approaching the upper limit of the size classification (40-foot height), the upper limit of the capacity range is considered to be applicable to this dam; therefore, the spillway is classified to be inadequate.

b. Adequacy of Information. Available information, in conjunction with visual observations, is considered to be sufficient to make the following recommendations.

c. Urgency. The following recommendations should be implemented immediately or on a continuing basis.

d. Necessity for Additional Data. It is recommended that the dam and appurtenant structures should be investigated and evaluated by a professional engineer experienced in design and construction of dams to more accurately ascertain the consequences of the observed conditions and the overall integrity of the dam and appurtenant structures, and to develop plans for remedial measures.

7.2 Recommendations/Remedial Measures. It is recommended that the following recommendations be implemented immediately or on a continuing basis:

1. The owner should immediately retain a professional engineer experienced in design and construction of dams for detailed evaluation of the dam and appurtenant structures and to prepare and execute plans for:

a. Controlling swampy conditions at the downstream toe of the dam and evaluating the stability of the embankment in view of these conditions. The detailed evaluation of the dam should include, but not be limited to, subsurface investigations, material testing, and seepage and stability analyses.

2. The structural and operational condition of the outlet facilities should be evaluated and necessary maintenance performed.

3. The crest of the embankment should be surveyed and low spots filled to design elevation.

4. Around-the-clock surveillance should be provided during unusually heavy runoff and a formal warning system should be developed to alert the downstream residents in the event of emergencies.

5. The dam and appurtenant structures should be inspected regularly and necessary maintenance performed. A review of the regional geology indicates that some deep coal mine workings may exist in the vicinity of the dam site. Therefore, future inspections should include a search for any indications of subsidence.

APPENDIX A

CHECKLIST
VISUAL INSPECTION
PHASE I

APPENDIX A

CHECKLIST
VISUAL INSPECTION
PHASE I

NAME OF DAM Big Brown Dam COUNTY Cambria STATE Pennsylvania ID# NDI I.D. PA-502 DER I.D. 11-1

TYPE OF DAM Earth HAZARD CATEGORY High

DATE(S) INSPECTION November 27, 1979 WEATHER Sunny TEMPERATURE 40s

POOL ELEVATION AT TIME OF INSPECTION 1675.5 M.S.L. TAILWATER AT TIME OF INSPECTION 1642± M.S.L.

INSPECTION PERSONNEL:

Bilgin Erel

Wah Tak Chan

REVIEW INSPECTION PERSONNEL:
(December 28, 1979)

E. D'Appolonia

L. D. Andersen

J. H. Poellot

B. Erel

B. Erel RECORDER

VISUAL INSPECTION
PHASE I
EMBANKMENT

VISUAL EXAMINATION OF	OBSERVATIONS	REMARKS OR RECOMMENDATIONS
SURFACE CRACKS	None	
UNUSUAL MOVEMENT OR CRACKING AT OR BEYOND THE TOE	None	
SLOUGHING OR EROSION OF EMBANKMENT AND ABUTMENT SLOPES	None	
VERTICAL AND HORIZONTAL ALIGNMENT OF THE CREST	See Plate 6 for the crest profile.	
RIPRAP FAILURES	None	

VISUAL INSPECTION
PHASE I
EMBANKMENT

VISUAL EXAMINATION OF	OBSERVATIONS	REMARKS OR RECOMMENDATIONS
JUNCTION OF EMBANKMENT AND ABUTMENT, SPILLWAY AND DAM	No signs of distress other than the seepage condition described below and shown in Plate 5.	
ANY NOTICEABLE SEEPAGE	A significant seepage point is located near the left abutment/embankment interface. The discharge is estimated to be one-half to one cfs. See Plate 5 for other seepage points and wet and swampy areas below the toe of the dam.	This seepage should be monitored.
STAFF GAGE AND RECORDER	An inclined pipe with elevation markers serves as a staff gage. There is no recorder.	
DRAINS	None	

VISUAL INSPECTION
PHASE I
OUTLET WORKS

VISUAL EXAMINATION OF	OBSERVATIONS	REMARKS OR RECOMMENDATIONS
CRACKING AND SPALLING OF CONCRETE SURFACES IN OUTLET CONDUIT	(The outlet facilities were not accessible for inspection.)	
INTAKE STRUCTURE	Submerged	
OUTLET STRUCTURE	The outlet pipe directly discharges into an earth channel. There is no outlet structure.	
OUTLET CHANNEL	In fair condition.	
EMERGENCY GATE	The water authority personnel reported that the operational condition of the reservoir blow-off valve was questionable. The operational condition of this valve was not observed.	The operational condition of the blow-off valve and other outlet facilities should be reevaluated and necessary maintenance performed.

VISUAL INSPECTION
PHASE I
UNGATED SPILLWAY

VISUAL EXAMINATION OF	OBSERVATIONS	REMARKS OR RECOMMENDATIONS
CONCRETE WEIR	The emergency spillway has no overflow weir structure.	
APPROACH CHANNEL	Lake. Free of debris.	
DISCHARGE CHANNEL	Rock-cut channel. In good condition.	
BRIDGE AND PIERS	None	

VISUAL INSPECTION
PHASE I
GATED SPILLWAY

VISUAL EXAMINATION OF	OBSERVATIONS	REMARKS OR RECOMMENDATIONS
CONCRETE SILL	(The dam has no gated spillway.) Not applicable	
APPROACH CHANNEL	Not applicable	
DISCHARGE CHANNEL	Not applicable	
BRIDGE PIERS	Not applicable	
GATES AND OPERATION EQUIPMENT	Not applicable	

VISUAL INSPECTION
PHASE I
INSTRUMENTATION

VISUAL EXAMINATION OF	OBSERVATIONS	REMARKS OR RECOMMENDATIONS
MONUMENTATION/SURVEYS	None	
OBSERVATION WELLS	None	
WEIRS	None	
PIEZOMETERS	None	
OTHER	None	

VISUAL INSPECTION
PHASE I
RESERVOIR

VISUAL EXAMINATION OF	OBSERVATIONS	REMARKS OR RECOMMENDATIONS
SLOPES	No significant shoreline erosion.	
SEDIMENTATION	Unknown	
UPSTREAM RESERVOIRS	None	

VISUAL INSPECTION
PHASE I
DOWNSTREAM CHANNEL

VISUAL EXAMINATION OF	OBSERVATIONS	REMARKS OR RECOMMENDATIONS
CONDITION (OBSTRUCTIONS, DEBRIS, ETC.)	There are no obstructions that would affect the discharge capacity of the spillway.	
SLOPES	No pertinent features that should affect the performance of the dam.	
APPROXIMATE NUMBER OF HOMES AND POPULATION	There are approximately 10 homes within the potential flood plain of the dam approximately one mile downstream. Population: approximately 50.	

APPENDIX B

CHECKLIST
ENGINEERING DATA
DESIGN, CONSTRUCTION, OPERATION
AND HYDROLOGIC AND HYDRAULIC
PHASE I

APPENDIX B

CHECKLIST
ENGINEERING DATA
DESIGN, CONSTRUCTION, OPERATION
PHASE I

NAME OF DAM Big Brown Dam
ID# NDI I.D. PA-502
DER I.D. 11-1

ITEM	REMARKS
AS-BUILT DRAWINGS	Design drawings are available in the state files.
REGIONAL VICINITY MAP	See Plate 1.
CONSTRUCTION HISTORY	The dam was designed by an engineer from Spangler, Pennsylvania, and constructed by Northern Cambria Water Company, with completion in 1910.
TYPICAL SECTIONS OF DAM	See Plate 2.
OUTLETS - PLAN - DETAILS - CONSTRAINTS - DISCHARGE RATINGS	See Plate 3.

CHECKLIST
ENGINEERING DATA
DESIGN, CONSTRUCTION, OPERATION
PHASE I

ITEM	REMARKS
RAINFALL/RESERVOIR RECORDS	Not recorded
DESIGN REPORTS	Not available
GEOLOGY REPORTS	Not available
DESIGN COMPUTATIONS HYDROLOGY & HYDRAULICS DAM STABILITY SEEPAGE STUDIES	Not available
MATERIALS INVESTIGATIONS BORING RECORDS LABORATORY FIELD	Not available

CHECKLIST
ENGINEERING DATA
DESIGN, CONSTRUCTION, OPERATION
PHASE I

ITEM	REMARKS
POST CONSTRUCTION SURVEYS OF DAM	None reported
BORROW SOURCES	Unknown
MONITORING SYSTEMS	None
MODIFICATIONS	None
HIGH POOL RECORDS	Not recorded

CHECKLIST
ENGINEERING DATA
DESIGN, CONSTRUCTION, OPERATION
PHASE I

ITEM	REMARKS
POST CONSTRUCTION ENGINEERING STUDIES AND REPORTS	A seepage condition which was observed on the left abutment/embankment interface was investigated during 1921 by Gannett, Seely, and Fleming, Consulting Engineers of Harrisburg, Pennsylvania.
PRIOR ACCIDENTS OR FAILURE OF DAM DESCRIPTION REPORTS	None reported
MAINTENANCE OPERATION RECORDS	Not recorded
SPILLWAY PLAN SECTIONS DETAILS	See Plate 2.
OPERATING EQUIPMENT PLANS AND DETAILS	See Plate 3.

CHECKLIST
ENGINEERING DATA
HYDROLOGIC AND HYDRAULIC

DRAINAGE AREA CHARACTERISTICS: 0.55 square mile

ELEVATION, TOP OF NORMAL POOL AND STORAGE CAPACITY: 1675.5 (51 acre-feet)

ELEVATION, TOP OF FLOOD CONTROL POOL AND STORAGE CAPACITY: 1680.3 (76 acre-feet)

ELEVATION, MAXIMUM DESIGN POOL: 1681 (as designed)

ELEVATION, TOP OF DAM: 1680.3 (measured low spot)

SPILLWAY:

a. Elevation 1675.5

b. Type Rock-cut channel

c. Width 22 feet

d. Length Not applicable

e. Location Spillover Center of embankment

f. Number and Type of Gates Not applicable

OUTLET WORKS:

a. Type 20-inch cast-iron pipe

b. Location Near left abutment

c. Entrance Inverts 1650±

d. Exit Inverts 1641±

e. Emergency Drawdown Facilities 20-inch cast-iron pipe

HYDROMETEOROLOGICAL GAGES:

a. Type None

b. Location None

c. Records None

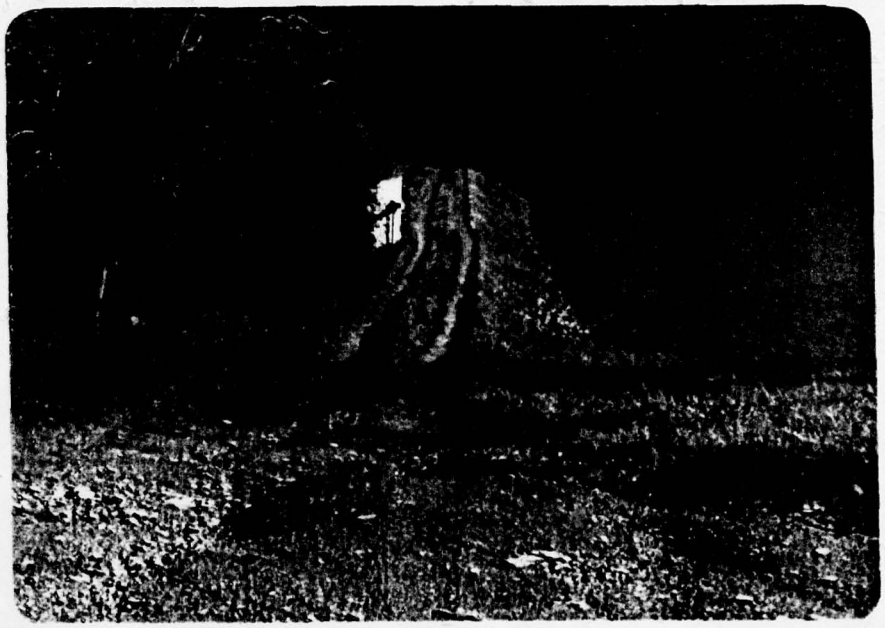
MAXIMUM NONDAMAGING DISCHARGE: 600 cfs (spillway capacity)

APPENDIX C

PHOTOGRAPHS

LIST OF PHOTOGRAPHS
BIG BROWN DAM
NDI I.D. PA-502
NOVEMBER 27, 1979

PHOTOGRAPH NO.	DESCRIPTION
1	Crest (looking southeast).
2	Emergency spillway approach channel.
3	Emergency spillway control section and discharge channel.
4	Outlet pipe valve.
5	Primary spillway outlet pipe.
6	Flood plain (Mile 1.0). Brown Run flowing left to right.



Photograph No. 1

Crest (looking southeast).

Photograph No. 2

Emergency spillway approach channel.

Photograph No. 3

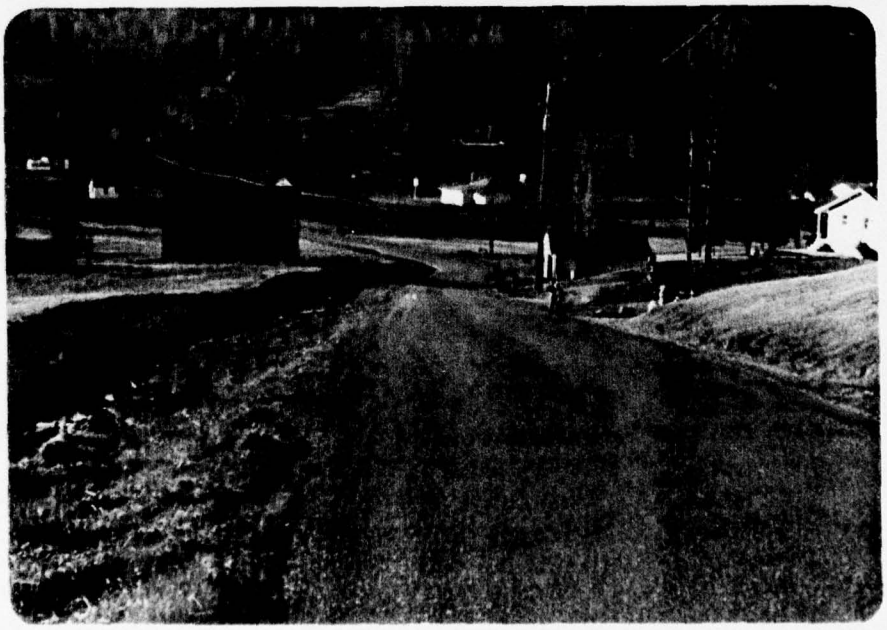
Emergency spillway control section and discharge channel.

Photograph No. 4

Outlet pipe valve.

Photograph No. 5

Primary spillway outlet pipe.



Photograph No. 6

Flood plain (Mile 1.0). Brown Run flowing left to right.

APPENDIX D

HYDROLOGY AND HYDRAULICS ANALYSES

HYDROLOGY AND HYDRAULIC ANALYSIS
DATA BASE

NAME OF DAM: Big Brown Dam (NDI I.D. PA-502)

PROBABLE MAXIMUM PRECIPITATION (PMP) = 23.6 INCHES/24 HOURS[1]

STATION	1	2	3	4	5
Station Description	Reservoir	Dam			
Drainage Area (square miles)	0.55	-			
Cumulative Drainage Area (square miles)	0.55	0.55			
Adjustment of PMF for Drainage Area (%)[2]	Zone 7				
6 Hours	102	-			
12 Hours	120	-			
24 Hours	130	-			
48 Hours	140	-			
72 Hours	-	-			
Snyder Hydrograph Parameters					
Zone[3]	19	-			
C_p/C_t[4]	0.45/1.84	-			
L (miles)[5]	1.1	-			
L_{ca} (miles)[5]	0.5	-			
$t_p = C_t(L \cdot L_{ca})^{0.3}$ (hours)	1.54	-			
Spillway Data					
Crest Length (ft)	-	22			
Freeboard (ft)	-	4.8			
Discharge Coefficient	-	2.65			
Exponent	-	1.5			

(1) Hydrometeorological Report 33 (Figure 1), U.S. Army, Corps of Engineers, 1956.

(2) Hydrometeorological Report 33 (Figure 2), U.S. Army, Corps of Engineers, 1956.

(3) Hydrological zone defined by Corps of Engineers, Baltimore District, for determining Snyder's Coefficients (C_p and C_t).

(4) Snyder's Coefficients.

(5) L = Length of longest water course from outlet to basin divide.
L_{ca} = Length of water course from outlet to point opposite the centroid of drainage area.

STORAGE VS. ELEVATION

ELEVATION	ΔH, FEET	AREA (ACRES)[1]	ΔVOLUME (ACRE-FEET)[2]	STORAGE (ACRE-FEET)
1700	20	11.9	169.9	243.2
1680	4.5	5.5	22.7	73.3
1675.5[4]		4.6		50.6
Reservoir Bottom	-	-	50.6[3]	0

(1) Planimetered from USGS maps.

(2) ΔVolume = $\Delta H/3\ (A_1 + A_2 + \sqrt{A_1 A_2})$.

(3) From PennDER files.

(4) Normal pool elevation was obtained from design drawing.

```
**********
FLOOD HYDROGRAPH PACKAGE (HEC-1)
DAM SAFETY VERSION      JULY 1978
  LAST MODIFICATION  26 FEB 79
**********
    1                A1       SNYDER UNIT HYDROGRAPH,FLOOD ROUTING AND DAM OVERTOPPING ANALYSES
    2                A2       BIG BROWN DAM,CAMBRIA COUNTY,NDI-I.D.PA.502      PROJECT NO.79-543-09
    3                A3       FOR 20%,30%,40%,50%,60%,70%,80%,90%,AND 100% PMF
    4                B     300        0       15        0        0        0        0        0       -4        0
    5                B1      5
    6                J       1        9        1
    7                J1   0.20     0.30     0.40     0.50     0.60     0.70     0.80     0.90     1.00
    8                K       0        1                                          1
    9                K1       CALCULATION OF SNYDER INFLOW HYDROGRAPH TO BIG BROWN RESERVOIR
   10                M       1        1    0.55             0.55                                    1
   11                P             23.6      102      120      130      140
   12                T                                                      1.0      .05           0.0132
   13                W    1.54     0.45
   14                X    -1.0    -0.05      2.0
   15                K       1        2                                          1
   16                K1       ROUTING FLOW THROUGH BIG BROWN DAM (NDI-I.D.PA.502)
   17                Y                                         1        1
   18                Y1      1                                                -1675.5
   19                $S    0.0     50.6     73.3    243.2
   20                $E 1643.0  1675.5  1680.0  1700.0
   21                $$ 1675.5     22.0     2.65      1.5
   22                $D 1680.3     3.08      1.5    290.0
   23                $L   50.0    150.0    195.0    233.0    258.0    278.0    290.0
   24                $V 1680.3  1680.6  1680.9  1681.1  1681.5  1682.2  1683.3
   25                K      99
```

PEAK FLOW AND STORAGE (END OF PERIOD) SUMMARY FOR MULTIPLE PLAN-RATIO ECONOMIC COMPUTATIONS
FLOWS IN CUBIC FEET PER SECOND (CUBIC METERS PER SECOND)
AREA IN SQUARE MILES (SQUARE KILOMETERS)

OPERATION	STATION	AREA	PLAN	RATIOS APPLIED TO FLOWS RATIO 1 .20	RATIO 2 .30	RATIO 3 .40	RATIO 4 .50	RATIO 5 .60	RATIO 6 .70	RATIO 7 .80	RATIO 8 .90	RATIO 9 1.00
HYDROGRAPH AT	1	.55	1	252.	378.	504.	630.	756.	882.	1008.	1134.	1260.
	(	1.42)	(	7.14)(	10.71)(	14.27)(	17.84)(	21.41)(	24.98)(	28.55)(	32.12)(	35.68)
ROUTED TO	2	.55	1	241.	364.	488.	603.	741.	875.	1000.	1127.	1254.
	(	1.42)	(	6.81)(	10.31)(	13.81)(	17.07)(	20.99)(	24.77)(	28.33)(	31.92)(	35.51)

SUMMARY OF DAM SAFETY ANALYSIS

PLAN 1 .....

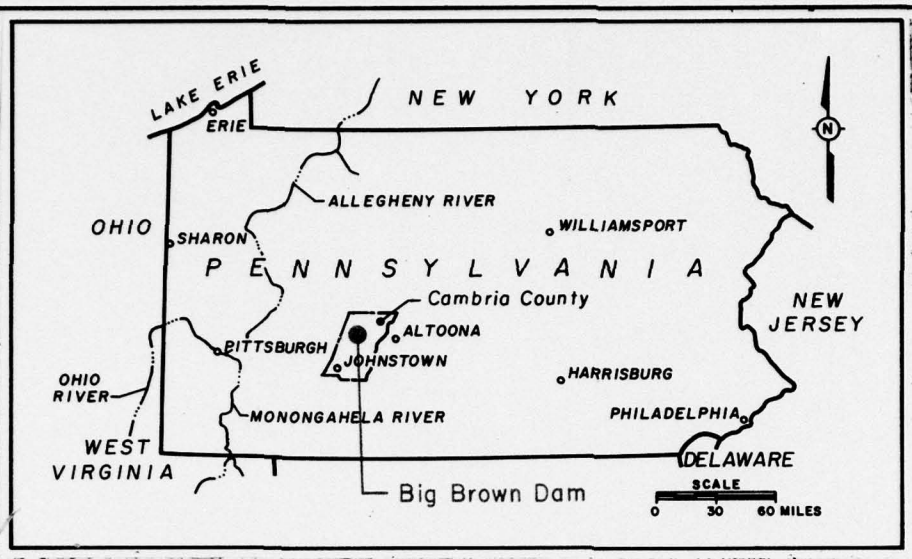
	INITIAL VALUE	SPILLWAY CREST	TOP OF DAM
ELEVATION	1675.50	1675.50	1680.30
STORAGE	51.	51.	76.
OUTFLOW	0.	C.	613.

RATIO OF PMF	MAXIMUM RESERVOIR W.S.ELEV	MAXIMUM DEPTH OVER DAM	MAXIMUM STORAGE AC-FT	MAXIMUM OUTFLOW CFS	DURATION OVER TOP HOURS	TIME OF MAX OUTFLOW HOURS	TIME OF FAILURE HOURS
.20	1678.07	0.00	64.	241.	0.00	41.75	0.00
.30	1678.89	0.00	68.	364.	0.00	41.75	0.00
.40	1679.62	0.00	71.	488.	0.00	41.75	0.00
.50	1680.25	0.00	75.	603.	0.00	41.75	0.00
.60	1680.65	.35	79.	741.	2.25	41.50	0.00
.70	1680.86	.56	81.	875.	3.00	41.50	0.00
.80	1681.02	.72	82.	1000.	3.50	41.50	0.00
.90	1681.15	.85	83.	1127.	4.25	41.25	0.00
1.00	1681.27	.97	84.	1254.	4.75	41.25	0.00

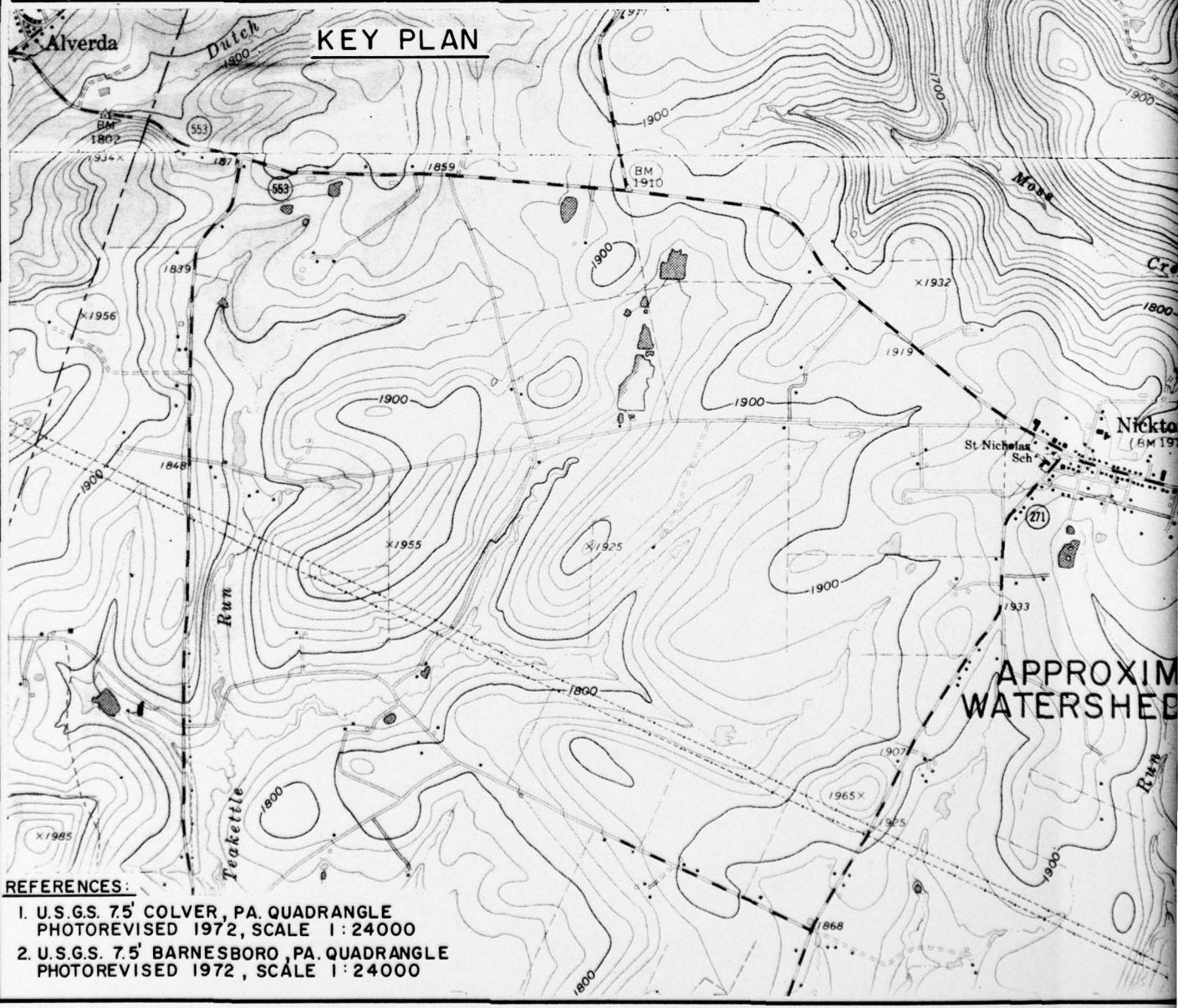
APPENDIX E

PLATES

DRAWN BY	ACS	CHECKED BY	BE	2/14/80	DRAWING NUMBER 79-543-826
	11-15-79	APPROVED BY	JMD	2/14/80	



KEY PLAN



REFERENCES:

1. U.S.G.S. 7.5' COLVER, PA. QUADRANGLE PHOTOREVISED 1972, SCALE 1:24000
2. U.S.G.S. 7.5' BARNESBORO, PA. QUADRANGLE PHOTOREVISED 1972, SCALE 1:24000

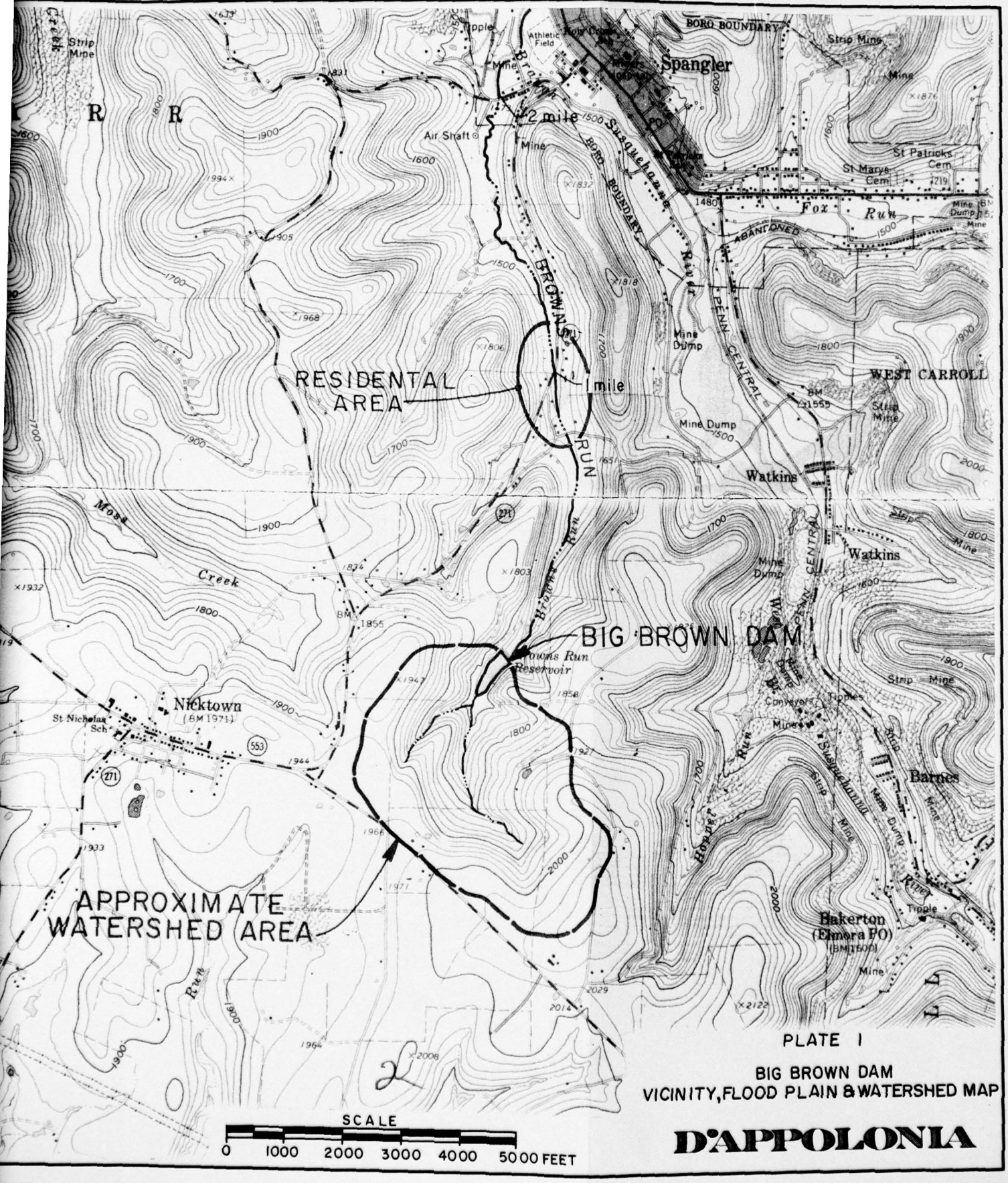
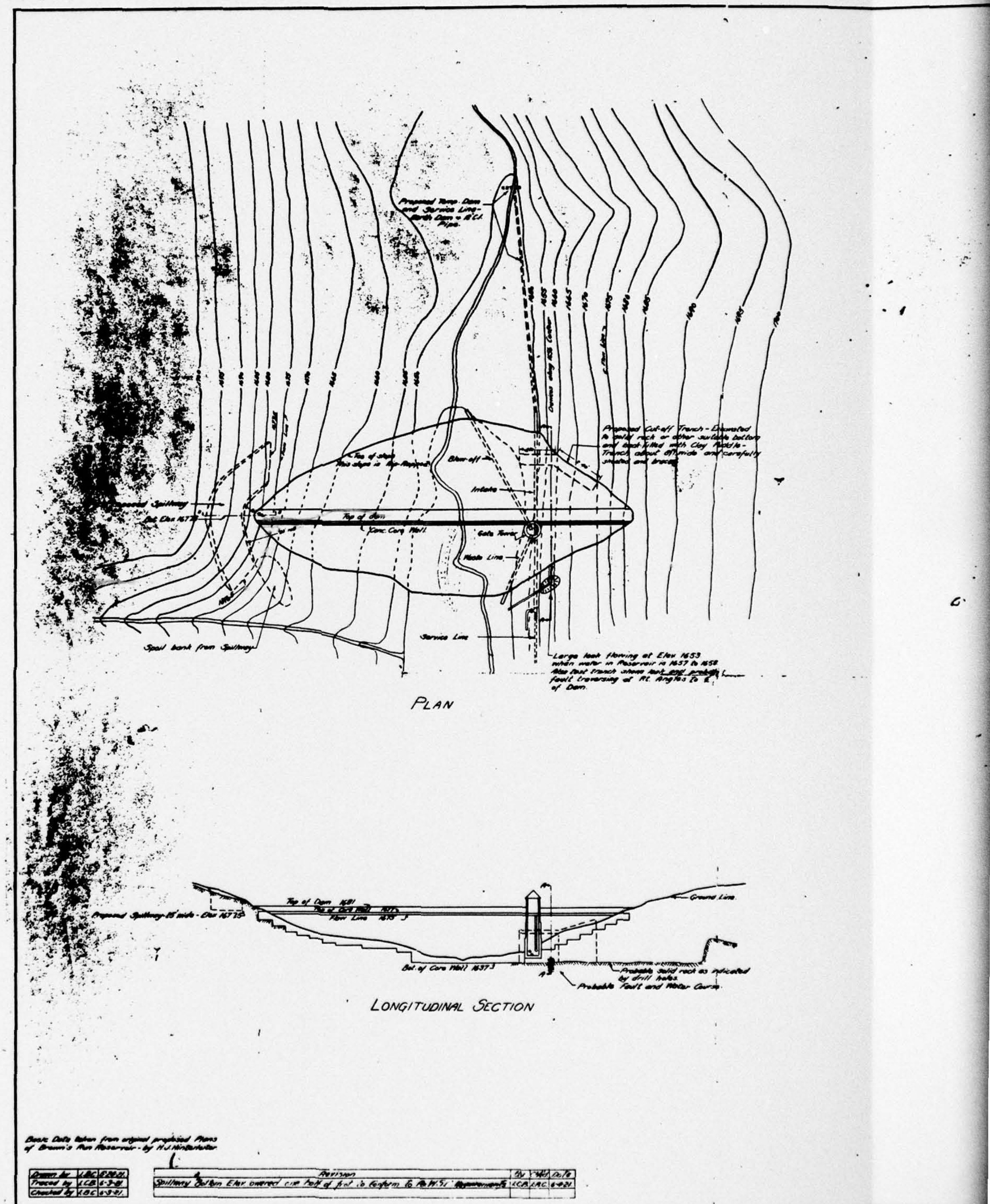


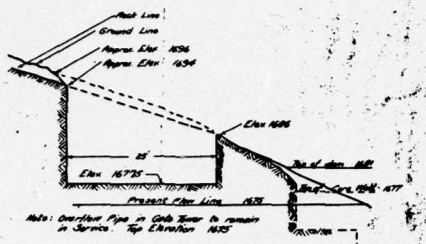
PLATE 1

BIG BROWN DAM
VICINITY, FLOOD PLAIN & WATERSHED MAP

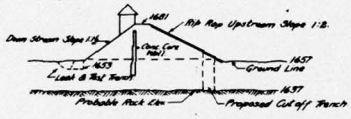
D'APPOLONIA

DRAWN BY	ACS 11-15-79	CHECKED BY APPROVED BY	13E JHP	2/14/80 5/14/80	DRAWING NUMBER	79-543-B27





CROSS SECTION OF SPILLWAY B-B
Scale 1"=10'



CROSS SECTION - A-A

OTHER MINOR IMPROVEMENTS AND REPAIRS
To be carried out at the time of Cut-Off and Spillway Construction.

1- The present intake Screen to be enclosed with galvanized wire cloth 2 meshes to the inch, 19 wire each way, using the old screen as a frame for it.
2- Sufficient fence to be built to ward off trespassers around the Reservoir. Fence to be 5' Strand barbed wire No. 9 B.C. and 5' Locust Posts 8' long and 3' in the ground or their equivalent.
3- The following improvements and Repairs to the Gate Tower :-
(a) Put Steel braces of 1 Channels or Second Hand R.R. rails against dam off sets to prevent it from bowing off of its seat.
(b) Provide extension stems and their stands for both the blow-off and Service line valves.
(c) Repair the windows and door and put wire cloth over the windows on the outside. Wire cloth to be 2 meshes to 1 inch & 19 Wire each way.
(d) Paint the total wood work of the Gate Tower, inside and out - including shingle roof. Paint to be good quality red.

NORTHERN CAMBRIA WATER COMPANY
PROPOSED CUT-OFF TRENCH & SPILLWAY
FOR
BROWNS RUN DAM

Scale 1"=40', Except as noted. June 1921

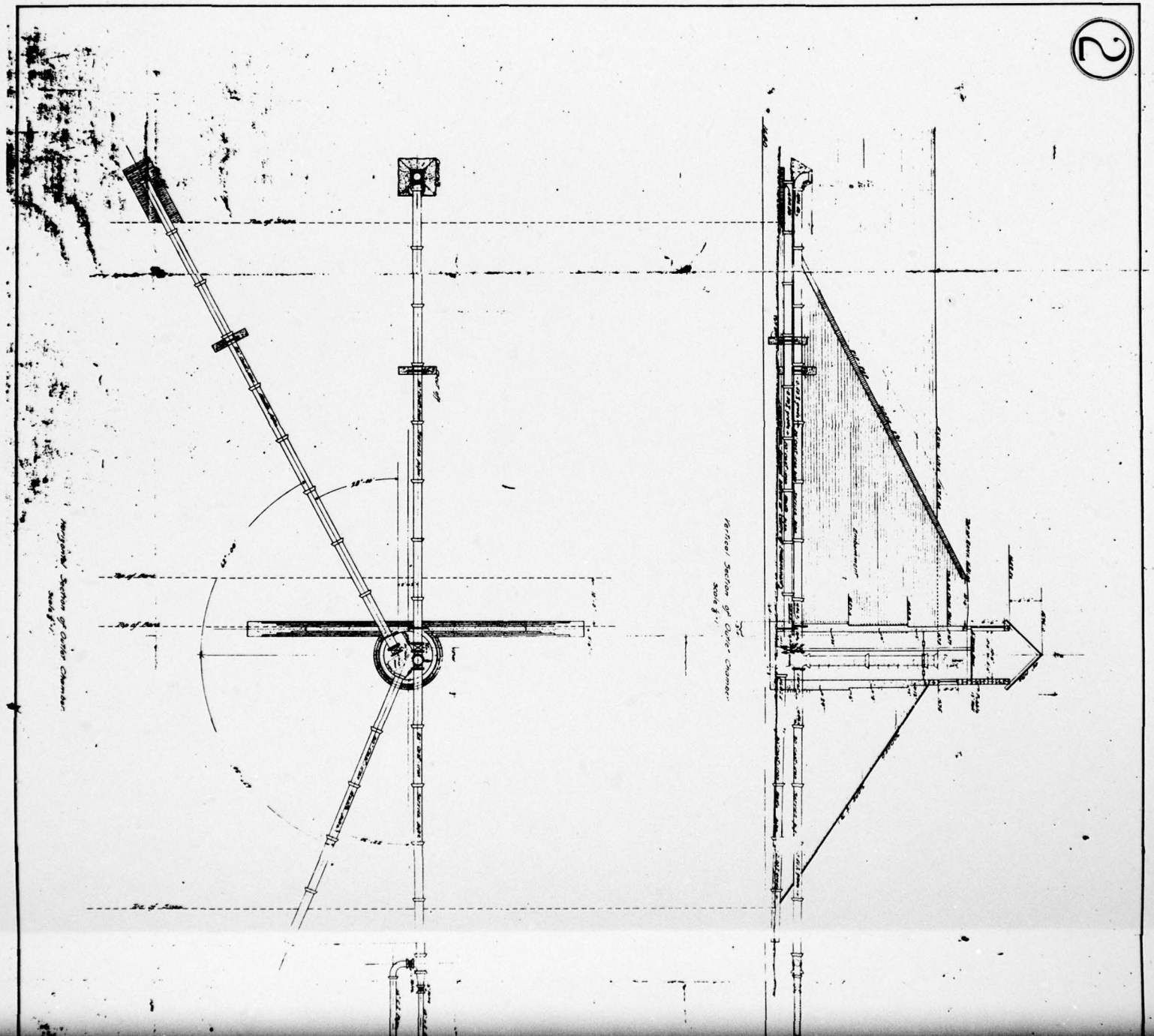
Gannett Seelye & Fleming, Inc.
Engineers
Harrisburg, Pa.

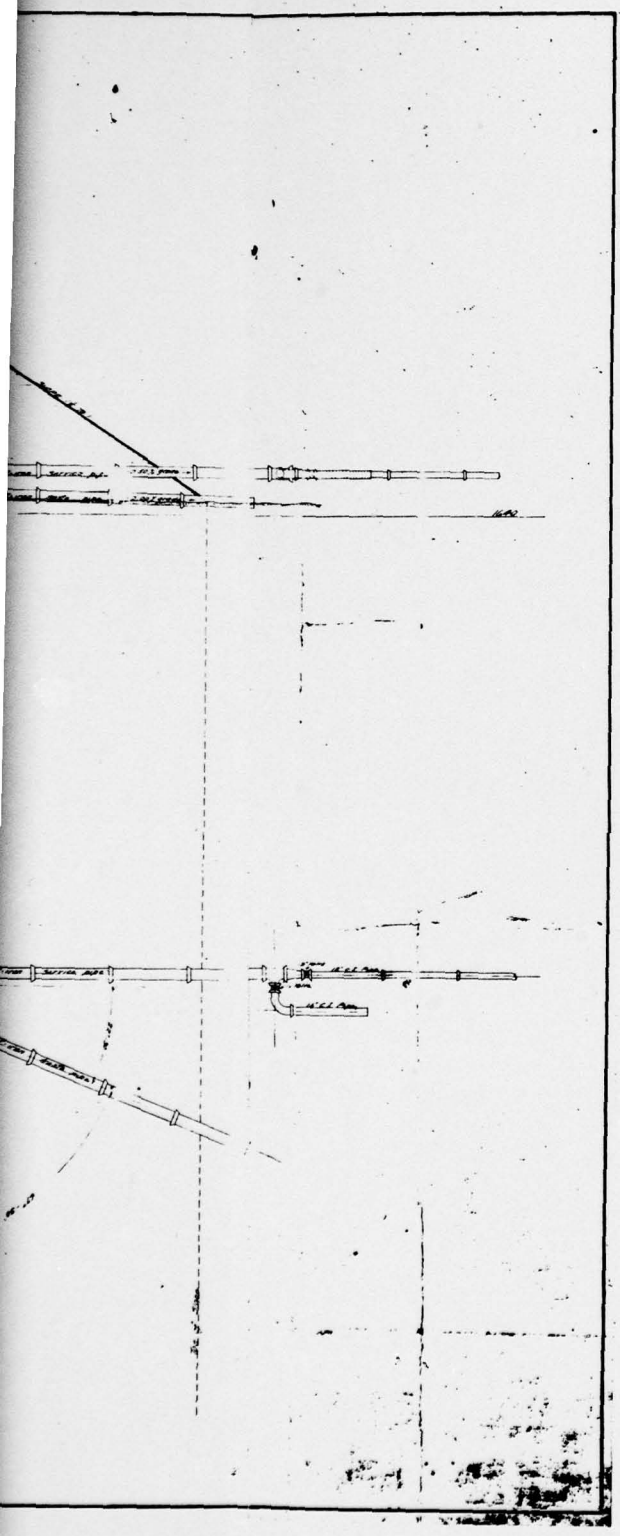
PLATE 2

2

DRAWN BY	ACS	CHECKED BY	BE	2/14/80	DRAWING NUMBER	79-543-B28
	11-15-79	APPROVED BY	JHD	2/14/80		

(2)





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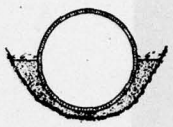
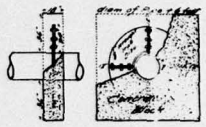
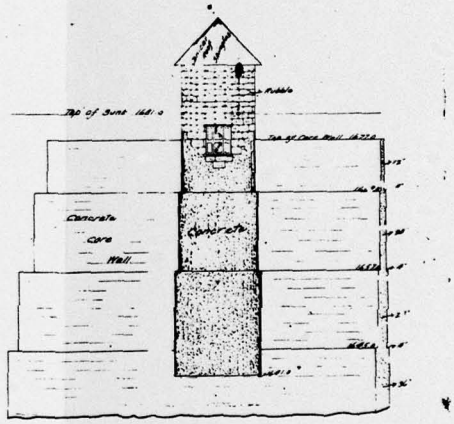


Concrete Cradle for Pipe



Cut-off for Pipes



Elevation of Outlet Chamber
Scale 1"=1'

NORTHERN CAMBRIA WATER CO.

BROWN'S RUN RESERVOIR

BARR TOWNSHIP, CAMBRIA CO., PA.

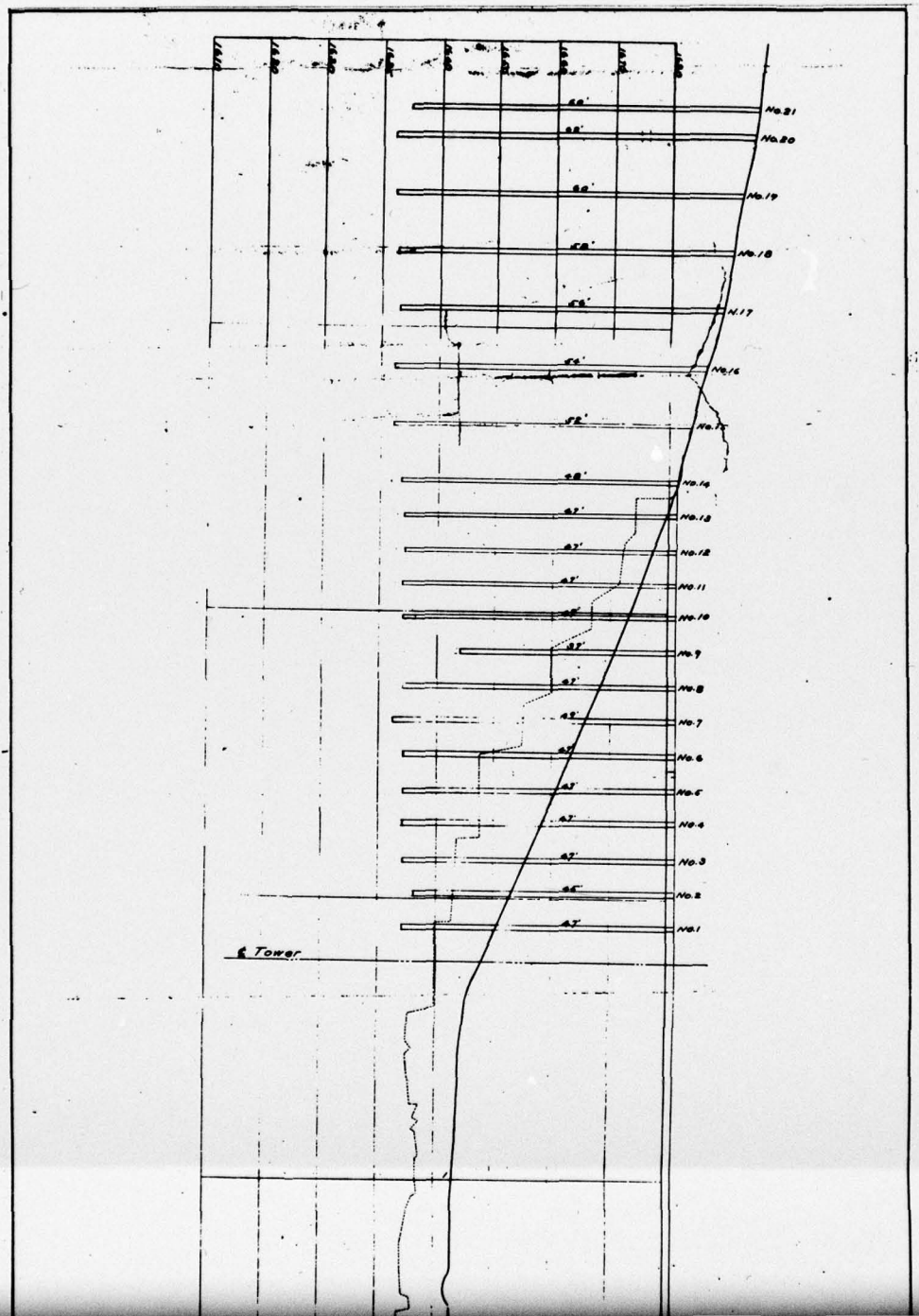
AUG. 1929

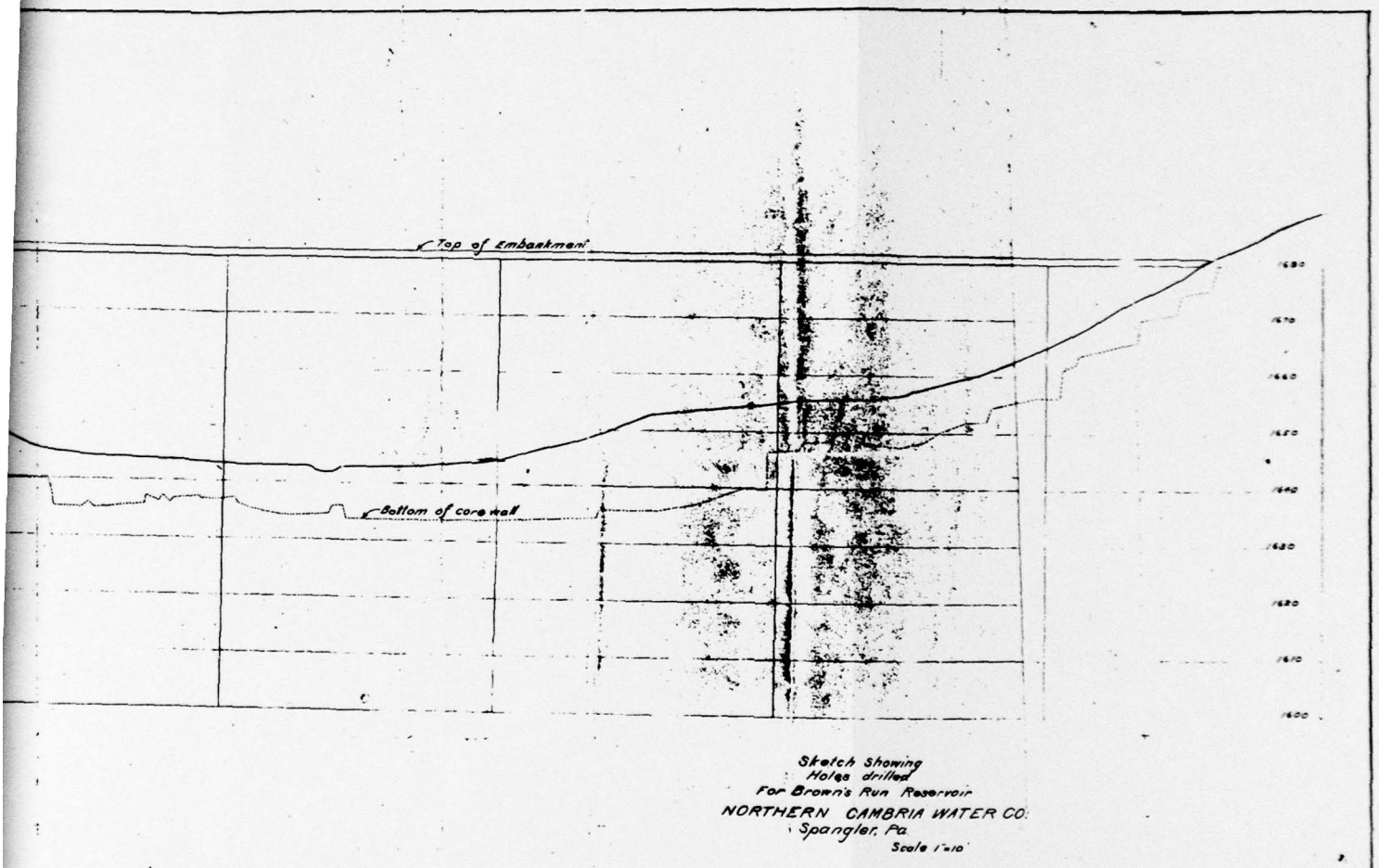
PLATE 3

2

D'APPOLONIA

DRAWN BY	ACS	CHECKED BY	BE	2/14/80	DRAWING NUMBER 79-543-B29
	11-15-79	APPROVED BY	JHP	2/14/80	





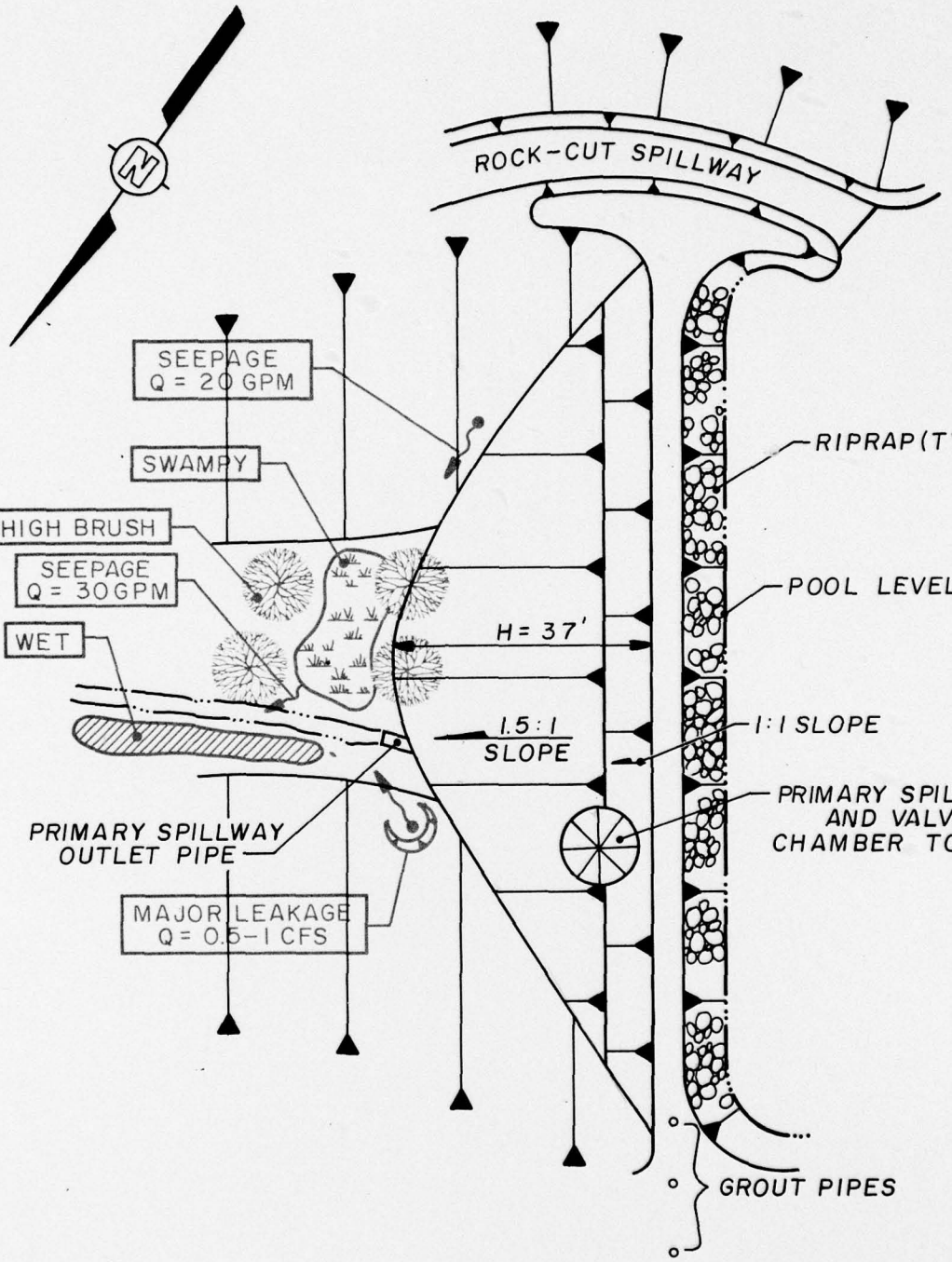
Sketch Showing
Holes drilled
For Brown's Run Reservoir
NORTHERN CAMBRIA WATER CO.
Spangler, Pa.
Scale 1"=10'

PLATE 4

2

D'APPOLONIA

DRAWN BY	ACS	CHECKED BY		DRAWING NUMBER	79-543-A23
	11-20-79	APPROVED BY			2/14/80



NOTES:

1. POOL LEVEL DATE OF INSPECTION: AT OVERFLOW SPILLWAY CREST LEVEL.

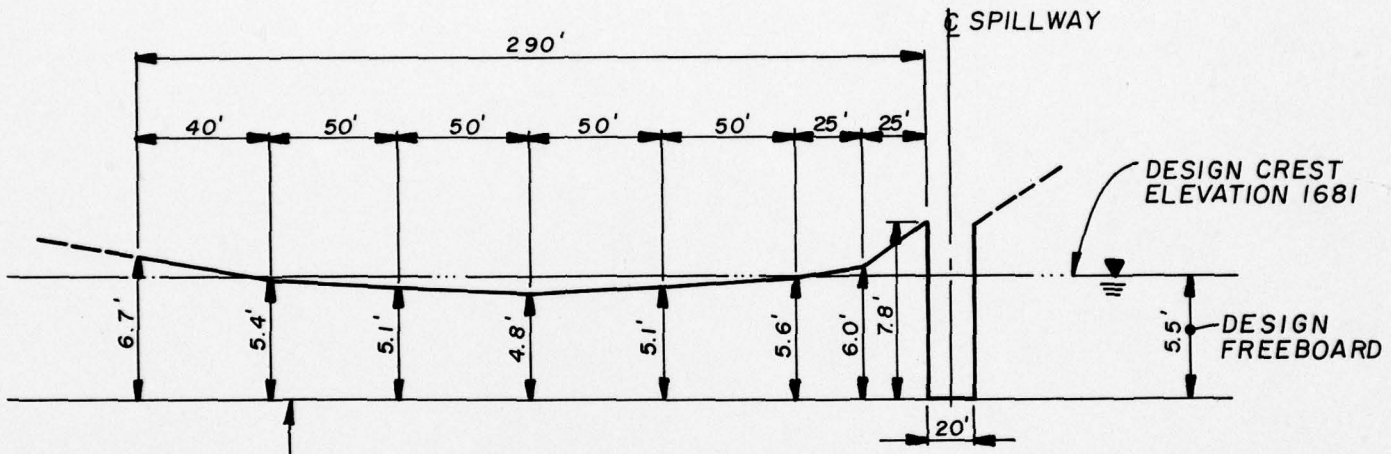
NOT TO SCALE

PLATE 5

BIG BROWN DAM
GENERAL PLAN
FIELD INSPECTION NOTES
FIELD INSPECTION DATE: NOV. 27, 1979

D'APPOLONIA

DRAWN BY	ACS	CHECKED BY	BE	2/14/80	DRAWING NUMBER 79-543-A24
	11-20-79	APPROVED BY	JHC	2/14/80	



DAM CREST PROFILE

(LOOKING DOWNSTREAM)

NOTES:

1. DAM CREST IS SURVEYED RELATIVE TO SPILLWAY CREST LEVEL
2. DATUM ELEVATION PER IS PER DESIGN DRAWINGS

PLATE 6

BIG BROWN DAM
DAM CREST SURVEY
FIELD INSPECTION DATE: NOV. 27, 1979

D'APPOLONIA

APPENDIX F

REGIONAL GEOLOGY

APPENDIX F

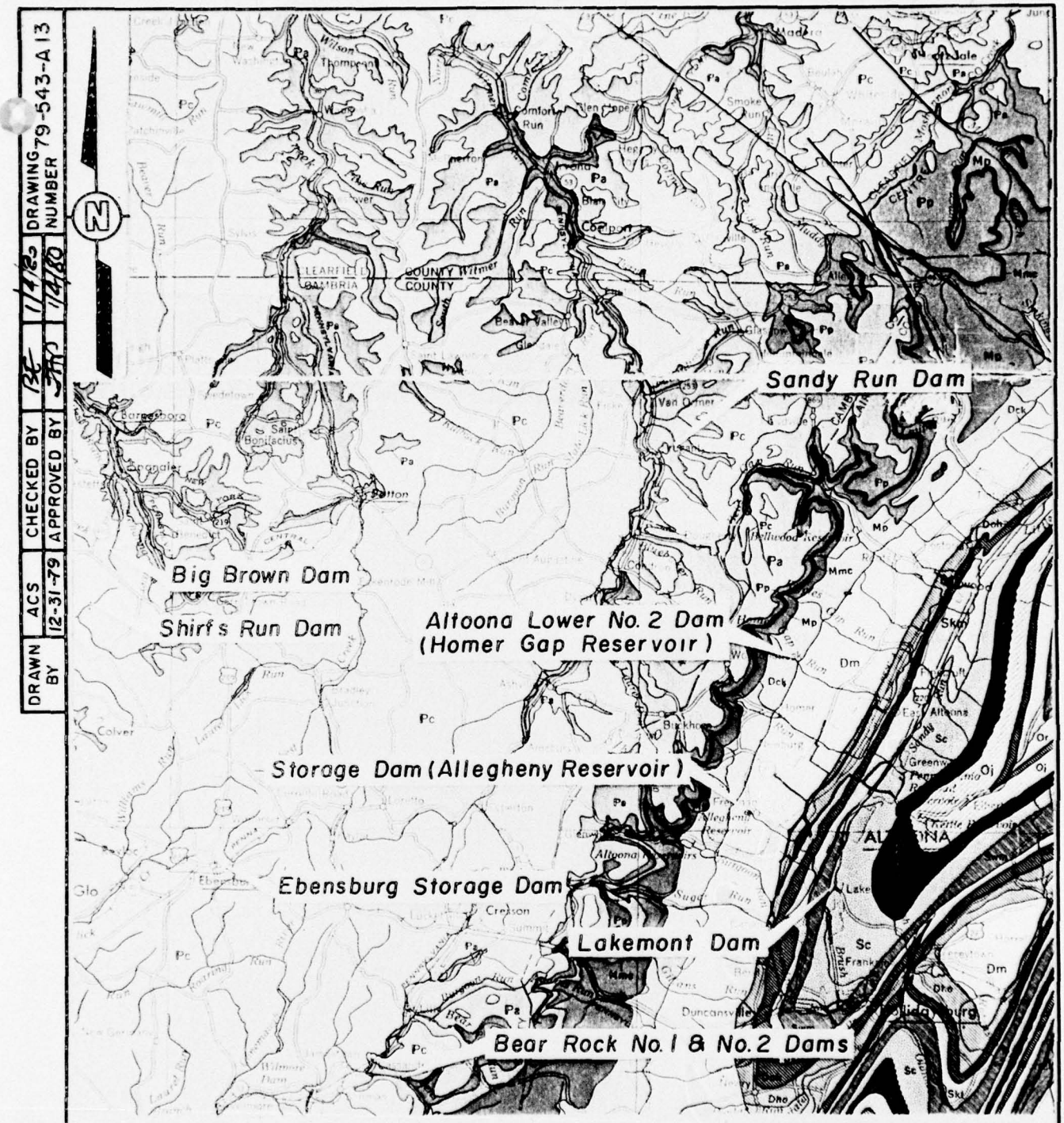
REGIONAL GEOLOGY

Big Brown Dam physiographically lies within the Allegheny Mountains section of the Appalachian Plateau Province. The dam site is on the west flank of the Laurel Hill anticline, which coincides with the east flank of the Barnesboro syncline in this area. The strata dip approximately 150 feet per mile to the west. Bedrock at the site consists of sedimentary rock strata of the Middle to Lower Conemaugh Group of the Pennsylvania Series. In general, strata of the Conemaugh Group consist of interbedded shale, claystone, sandstone, and several thin coal seams. The underlying Allegheny Group consists of sandstone and shale strata along with several coal seams.

The Lower Kittanning and Lower Freeport coal seams of the underlying Allegheny Group have been extensively mined in Cambria County. The Lower Kittanning coal seam, which is approximately 380 feet below the surface, has been mined. The Lower Freeport coal seam, approximately 180 feet below the surface, has also been mined. The site is underlain by the Barnes and Tucker Company Lancashire No. 15 mine (Lower Kittanning coal seam), but exact details of the mine operation were not determined. Therefore, depending on the type of mining and local geology, a potential for surface subsidence may exist.

The slopes in the vicinity of the reservoir are relatively gentle, reflecting the ease of weathering of the fine-grained Conemaugh rock strata. No large slides should occur, although minor creep may be expected.

DRAWN BY	ACS	CHECKED BY		DRAWING NUMBER 79-543-A13
	12-31-79	APPROVED BY		



SCALE

0 2 4 6 8 10 miles

REFERENCE:

GEOLOGIC MAP OF PENNSYLVANIA PREPARED BY COMMONWEALTH OF PENNA., DEPT. OF INTERNAL AFFAIRS, DATED 1960, SCALE 1" = 4 MILES

SANDY RUN, BIG BROWN, SHIRFS RUN EBENSBURG STORAGE, LAKEMONT, BEAR ROCK NO. 1 AND NO. 2 DAMS, (ALLEGHENY RESERVOIR) STORAGE DAM AND ALTOONA LOWER NO. 2 (HOMER GAP RESERVOIR)

GEOLOGY MAP

DAPTPOLONIA

DRAWN BY	ACS	CHECKED BY		DRAWING NUMBER 79-543-A18
	12-31-79	APPROVED BY		

LEGEND:

Pc — **Conemaugh Formation**

Cyclic sequences of red and gray shales and siltstones with thin limestones and coals; massive Mahoning Sandstone commonly present at base; Ames Limestone present in middle of sections; Brush Creek Limestone in lower part of section.

Pottsville Group

Light gray to white, coarse grained sandstones and conglomerates with some mineable coal; includes Sharp Mountain, Schuylkill, and Tumbling Run Formations.

Pa — **Allegheny Group**

Cyclic sequences of sandstone, shale, limestone and coal, numerous commercial coals, limestones thicken westward; Vanport Limestone in lower part of section; includes Freeport, Kittanning, and Clarion Formations.

Sc — **Clinton Group**

Predominantly Rose Hill Formation - Reddish purple to greenish gray, thin to medium bedded, fossiliferous shale with intertonguing "iron sandstones" and local gray, fossiliferous limestone; above the Rose Hill is brown to white quartzitic sandstone (Keefer) interbedded upward with dark gray shale (Rochester).

Dm — **Marine beds**

Gray to olive brown shales, graywackes, and sandstones; contains "Chemung" beds and "Portage" beds including Burket, Brallier, Harrell, and Trimmers Rock; Tully Limestone at base.

Pocono Group

Predominantly gray, hard, massive, cross-bedded conglomerate and sandstone with some shale; includes in the Appalachian Plateau Burgoon, Shenango, Cuyahoga, Cussewago, Corry, and Knapp Formations; includes part of "Oswayo" of M. L. Fuller in Potter and Tioga counties.

Do — **Oriskany Formation**

White to brown, fine to coarse grained, partly calcareous, locally conglomeratic, fossiliferous sandstone (Ridgeley) at the top, dark gray, cherty limestone with some interbedded shales and sandstones below (Shriver).

Tuscarora Formation

White to gray, medium to thick bedded; fine grained, quartzitic sandstone, conglomeratic in part.

Marcellus Formation

Black, fissile, carbonaceous shale with thick, brown sandstone (Turkey Ridge) in parts of central Pennsylvania.

Onondaga Formation

Greenish blue, thin bedded shale and dark blue to black, medium bedded limestone with shale predominant in most places; includes Selinsgrove Limestone and Needmore Shale in central Pennsylvania and Buttermilk Falls Limestone and Esopus Shale in easternmost Pennsylvania; in Lehigh Gap area includes Palmerton Sandstone and Bowmanstown Chert.

Dmo

Wills Creek Formation

Greenish gray, thin bedded, fissile shale with local limestone and sandstone zones; contains red shale and siltstone in the lower part.

Bloomsburg Formation

Red, thin and thick bedded shale and siltstone with local units of sandstone and thin impure limestone; some green shale in places.

McKenzie Formation

Greenish gray, thin bedded shale interbedded with gray, thin bedded, fossiliferous limestone; shale predominant at the base; intraformational breccia in the lower part. Absent in Harrisburg quadrangle and to the east.

Keyser Formation

Dark gray, highly fossiliferous, thick bedded, crystalline to nodular limestone; passes into Manlius, Rondout, and Decker Formations in the east.

Skt

Tonoloway Formation

Gray, highly laminated, thin bedded, argillaceous limestone; passes into Bossardville and Poxono Island beds in the east.

Dck — **Catskill Formation**

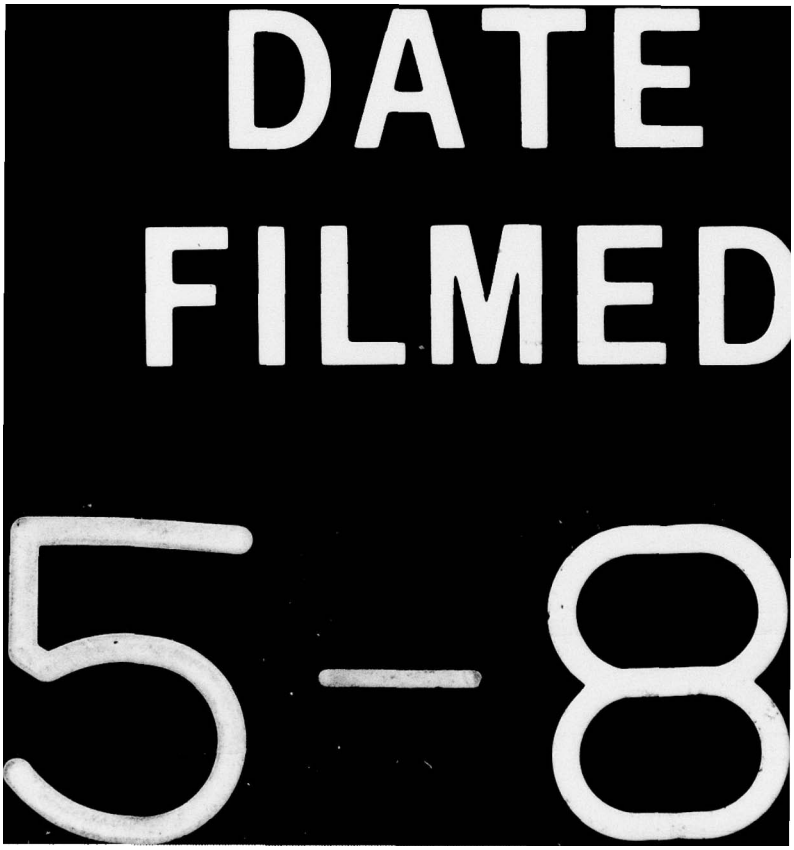
Chiefly red to brownish shales and sandstones; includes gray and greenish sandstone tongues named Elk Mountain, Honesdale, Shohola, and Delaware River in the east.

REFERENCE:

GEOLOGIC MAP OF PENNSYLVANIA PREPARED BY COMMONWEALTH OF PENNA. DEPT. OF INTERNAL AFFAIRS, DATED 1960, SCALE 1" = 4 MILES

GEOLOGY MAP LEGEND

D'APPOLONIA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